AN INVESTIGATION OF OYSTER PRODUCING AREAS IN LOUISIANA AND MISSISSIPPI DAMAGED BY FLOOD WATERS IN 1945

SPECIAL SCIENTIFIC REPORT: FISHERIES No. 8

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United States Department of the Interior
Oscar L. Chapman, Secretary
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Explanatory Note

The series embodies results of investigations, usually of restricted scope, intended to aid or direct management or utilization practices and as guides for administrative or legislative action. It is issued in limited quantities for the official use of Federal, State or cooperating agencies and in processed form for economy and to avoid delay in publication.

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INTRODUCTION

The Eightieth Congress of the United States of America enacted legislation in 1948 which provided in part:

> ". . . that money be appropriated to enable the Fish and Wildlife Service, Department of the Interior, to investigate and study the means and methods best adaptable to the rehabilitation, replanting and maintenance of the oysters beds in the State of Louisiana and Mississippi that have been or may be destroyed through the operation of the Bonnet Carre Spillway and through intrusion of fresh water and the blockage of natural passages west of the Mississippi River in the vicinity of Lake Mechant and Bayou Severin, Terrebonne Parrish, Louisiana, together with such sums that may be determined, as a result of such investigations and studies, to be necessary to rehabilitate, replant, and maintain such oyster beds. . ."

The passage of this legislation resulted from the Congressional representation of the respective states following the heavy floods which occurred on the lower Mississippi River in the Spring of 1945.

In the month of March, 1945 water levels in the Mississippi River reached flood crests so that the City of New Orleans was endangered. As a result, engineers of the Department of the Army Corps of Engineers opened the Bonnet Carre Spillway, situated some 25 miles above the city, to relieve the water pressure and lessen the danger to New Orleans. The Spillway was operated for a period of 56 days from March 24 until May 17 and diverted from the river bed a maximum flow of water of 318,000 second/feet. This mass of water was channelled into Lake Pontchartrain, where it spread out and flowed from the two exits of the lake into Lake Borgne and then eastward into the west end of Mississippi Sound (Fig. 1).

As the fresh water emerged from Lake Borgne, it passed through an oyster producing area and pushed back the more salty water of the Sound for a distance of 25 miles to the east. A total area of perhaps 200 square miles was affected but it is estimated that no more than one-third of this area at the most had any oysters present on the bottom. The water over the oyster beds nearest the source of river water remained fresh during the months of April, May and June. This resulted in the subsequent loss of most of the oyster population in that area. Competent investigators from both federal and state agencies have testified that the west and northeast sections of the area involved lost up to 100 per cent of the oysters and that the southeast section lost up to 50 per cent of its oyster population.

West of the Mississippi River, in the area of Lake Mechant, a similar situation occurred. In this section (Fig. 1), flood waters coming south along what is known as the Atchafalaya Floodway were confined by a series of levees as far as Morgan City. Here the volume of water was too great to pass through the artificial pass known as the Wax Lake Outlet, and the natural pass of the lower Atchafalaya River at Morgan City. As a result, the waters spread out over the marshland to the southeast and eventually some drained into Lake Mechant and its connecting bayous. This area is made up of privately leased bedding grounds for oysters. It has been testified that in July of 1945, the mortality here was 100 per cent except in the southeast part of the lake, where an unspecified portion of the oyster population escaped damage.

In view of the testimony presented at the Congressional hearings, there is no reason to doubt that a large quantity of oysters was destroyed in these areas in 1945, and that their loss was due to the intrusion of excessive flood waters. Nor is there any question that the losses created considerable hardship on not only the private lessees in the State of Louisiana and the oyster fishermen of Mississippi, but also on the people concerned in processing oysters for the market in both States. Representations were made to the Congress for reimbrusement for the damages suffered in the Mississippi Sound area to the extent of $3,000,000 and for over $1,000,000 in the Lake Mechant section.

SCOPE OF FISH AND WILDLIFE SERVICE SURVEY

It is not the purpose of this inquiry to investigate the validity of the financial claims, but rather to determine the desirability and methods for the rehabilitation, replanting and maintenance of the oyster beds in question.

The history of these oyster reefs in the period from 1945 until 1948, when the present survey was initiated, has revealed certain conditions which differentiates them naturally into three areas having distinct characteristics. These areas are described briefly to clarify the aims of this survey.

Area I. The ten major oyster producing reefs of the State of Mississippi lie in a 200 square mile section of Mississippi Sound, extending west from Cat Island to a line running due south from the town of Waveland. The southern part of this section includes natural reefs within the borders of the Louisiana marshes. This area experienced a 50 to 100 per cent mortality in the oyster population during the flood of 1945. The hurricane of 1947 caused additional damage which was primarily on the inshore shallow water reefs. In

the spring of 1949, there was no evidence of abnormal mortality here but neither was there much new growth. The majority of oysters on these reefs are less than the market size of 3 inches (Fig. 2).

Area II. This section comprises approximately 100 square miles with many small natural oyster reefs and some private oyster bedding grounds in the westernmost part of Mississippi Sound. It includes oyster bottoms under the jurisdiction of both Louisiana and Mississippi.

The oysters in this area are for the most part less than 2 inches in length and on many reefs there are only oyster spat less than a year old. This area suffered nearly 100 per cent mortality in 1945, was severely damaged again by the hurricane in 1947 and in the early part of 1949 more than half of the remaining small population of oysters died. The large dead shells on some of these reefs carry a succession of scars left by small oysters. These scars are the attached shells of small oysters which have died. Most of the scars are an inch or less in length and frequently lie one on top of the other. This indicates that altho gh young oysters have been setting here regularly in the past four seasons, they have nearly all died before reaching the age of one year (Fig. 2).

Area III. Lake Mechant and its connecting bayous cover an area of approximately 15 square miles lying 70 miles south west of the city of New Orleans. Perhaps 75 per cent of this area suffered severe oyster mortalities during the floods of 1945. After that time, the Lake apparently returned to normal. Most of the oysters here are located on privately leased bedding grounds. These grounds were put into use in 1946 and 1947. By the winter of 1947-48, oyster production was such that one of the lessees who had had the greatest losses in 1945 applied to the State of Louisiana for permission to lease an additional 150 acres in Lake Mechant. A preliminary survey of this section in the summer of 1948 showed that the oysters were in good condition and that there were prospects of normal production for the winter oyster season (Fig. 3).

With these considerations in mind, the present survey was planned to learn, if possible:

1. The reasons for poor growth of oysters in Area I,
2. The reasons for the annual mortalities of oysters in Area II,
3. The suitability of the environment for oysters in Area III,
4. The possibility of abnormal conditions continuing or being recurrent, and
5. The desirability of, and methods for, rehabilitating and maintaining the oyster reefs in question.

EQUIPMENT AND METHODS

The States of Louisiana and Mississippi provided the fullest cooperation for conducting this survey by providing the use of equipment, boats and personnel, as well as supplying detailed information concerning the different reefs. Louisiana, in addition, made available valuable records of salinity levels in Mississippi Sound collected during the period 1943-1947 and furnished the metal trays which were used at the sampling stations. Mr. F. N. Hansen, of the Water Resources Branch, Geological Survey, U. S. Department of the Interior, provided unpublished and provisional data on water discharge rates from the Pearl River Drainage Basin which were most informative.

The laboratory and experimental techniques were conducted at the U. S. Fisheries Laboratory, Pensacola, Florida. Standard techniques were employed in the various field and laboratory tests, but the description of these, as well as much of the detailed data collected at each station, have been omitted from the body of this report for the sake of clarity.

LABORATORY AND FIELD DATA AND THEIR INTERPRETATION

Condition of Oyster Reefs in May, 1949

During the course of this investigation, sampling stations were established in the different regions. These stations were selected because of their position with reference to the path of flood waters or because of their known potentiality in producing oysters. Some stations were visited only once for the purpose of establishing the variations in salinity across Mississippi Sound. There are other stations where we collected only hydrographic data because of the absence of oysters.

The conditions found on the more important reefs are described as of the end of May 1949 when salinity levels had returned to normal. Appendix A and Table 8 contain a more detailed discussion of the conditions on the individual reefs.

Area I. The different reefs in this area follow a certain similarity in pattern which permits a generalized statement concerning the suitability of this section for growing oysters during the first 6 months of 1949.

In this period the reefs suffered either a negligible mortality or that small amount which I should expect to find under the best conditions for oyster production. In May, all of the oysters were feeding, they had

spawned from 25 to 50 per cent of their sex products and the oyster meats were typical of good quality oysters during a spawning season. But in all cases, new shell growth was limited to 5 mms., or less and on 5 out of 7 reefs the deposition of new shell material was just starting. Ordinarily, along the Gulf Coast, the period from February to May is one of the major growing seasons of the year. In these months, oysters at the Pensacola Laboratory increased more than 50 per cent in average length.

Analyses of the total numbers of oysters present and the distribution of the different size groups on the reefs were not feasible because during the investigation, fishermen were harvesting the oysters and the State of Mississippi was transplanting seed oysters from one reef to another. In nearly all cases the reef bottoms were in good condition but were greatly in need of shells to catch the season's spat fall. The setting of young oysters, or spat fall, was very heavy in most locations. Clean shells were covered with 50 to 500 spat and the absence of oyster drills on all but the most easterly bars indicates that a reasonable percentage of these spat will survive.

In my opinion, the environment for the period January through May 1949 in this area, while not detrimental to the point of killing the oysters, had been distinctly unfavorable.

<u>Area II</u>. The reefs studied in this section were without exception, seriously depleted in numbers of oysters and amount of clean cultch. Ninety-five per cent of the oysters present were less than 3 inches long; the shells were smooth and free of fouling organisms. It is characteristic of oysters exposed to excess fresh water to have smooth white shells which are not fouled by other commensal organisms. The oysters had deposited almost no new shell material. Although in May, the oysters had commenced feeding, there was little significant development of the gonads. With one exception, there was no set of 1949 oysters. Station 10, the easternmost reef in the area had received a heavy spat fall and showed the least mortality, 26 per cent, of any reefs in Area II. The remaining stations had recent mortalities ranging from 45 to 95 per cent of the small population still present. The reef bottoms varied from good to poor. Many showed the effects of the 1947 hurricane in having excess sand and soft mud. Some of these conditions may be a lasting effect from the flooding of 1945, but at such a late date it is not possible to be certain of this.

The oysters in both Areas I and II are primarily on public reefs. The Louisiana Department of Wild Life and Fisheries and the Mississippi Seafoods Commission plant shells or seed oysters on

their respective reefs and, by controlling the oyster harvesting, maintain these reefs for the benefit of the citizens. There are a few privately held leases for oyster bedding grounds on the western edge of Area II within the State of Louisiana.

Area III. In Lake Mechant and its connecting bayous the oyster bottoms are privately leased. Most of these bottoms consist of a soft to firm mud and sand mixture. The initial surveys in February 1949 showed there was less than 5 per cent recent mortality and by May there were almost no further deaths. In May, the oysters were all in fair to good condition and were partially spawned. The oysters here are characterized by their heavy, eroded shells. Their stubby deeply cupped shape indicates that they are relatively slow growing. In the connecting bayous conditions are apparently more suitable for growth, since the oysters have a flat and more elongated shape. On one of the leases in Lake Mechant where the oysters had been allowed to grow and propagate naturally, 35 per cent of the oysters had reached the market size of 3 inches or longer. There was a moderate number of attached fouling organisms such as barnacles and mussels.

GROWTH

In each of the four years since the mass mortality in 1945, the oyster reefs in Mississippi Sound have experienced relatively good spat-falls. These small oysters have grown to approximately one inch in diameter and then for the most part died. Old shells on the reefs are covered with a succession of small scars, an inch or less long, superimposed on each other. This condition, striking in the western part of Area I, becomes less obvious and disappears on the bars to the east. The successive year groups of spat may be roughly identified by their position on the cultch and by the thickness of the shells but not by their overall size. Spat estimated from their size and shape to be 6 to 9 months old were frequently observed, having the same length as oysters apparently 1 to 2 years old. The assumption that many of these small oysters were relatively old was also borne out by the much heavier incidence of the cysts of *Nematopsis* in their tissues. In general, these cysts accumulate with the increasing age of the oyster.

The State of Mississippi, recognizing the failure of the oysters in this region to grow normally, transplanted 70,000 barrels from the Pass Christian reefs in the spring of 1949 to bars further east in an effort to provide a more suitable environment for the oysters. The wisdom of this transplanting is indicated by the results with small samples of these "non-growing" oysters which were transplanted experimentally to a favorable location near the laboratory at Pensacola, Florida.

In February a supply of oysters selected at random from the shallow water reef at Grand Island, Station 17, was brought to Pensacola along with samples from Lake Mechant. The oysters from the latter area were commercially dredged near. our Station 23. They were fairly small oysters but averaged twice the size of the Mississippi Sound samples. Length and breadth measurements were recorded for a sample of each of these groups and the oysters were placed in wire trays at a depth of 5 feet, approximately the depth of the bars from which they had been taken. These oysters were left undisturbed until the first of June, when size measurements were again recorded, as well as mortalities. At this time a third tray of oysters was added which had just been measured and transplanted from Station 17 to the laboratory. At the end of June the oysters were examined again. For comparative purposes, a tray of Florida oysters, native to this area, was maintained in the same location throughout the period of observation.

Table 1 summarizes the growth of these oysters, expressed as increase in length in millimeters, following their transplantation from the waters of Lake Mechant and Mississippi Sound to Pensacola, Florida.

The most significant point is that in the period February 7 - May 25 the average length of oysters remaining on the reef at Grand Island increased from 31 to 33 mms., or, practically not at all. The same stock of oysters moved to Florida for this period of time increased an average of 16 mm. or 51 per cent in length. The native Florida oysters increased 42 per cent during this period, while the Lake Mechant oysters increased but 16 per cent. The small increase for the latter group may be attributed to their initial larger average size. In general, the growth rate of oysters decreases as they become larger. The growth rates during the month of June were relatively low in the first three samples but in the new sample from Grand Island it was quite high. This was probably due to the stimulus of moving them to a new location.

Changes in the width of the oysters moved to Florida was disproportionately greater than length changes with the result that by the end of May, all samples, including the native controls had broadened to a more desirably shaped oyster. This is an expected result of separating clustered oysters and permitting them to grow unhampered.

During the course of these observations, water temperatures in Florida closely paralleled those in Mississippi Sound. However, the salinity in Florida averaged 18 ppm whereas in Mississippi Sound it averaged less than 5 ppm and for much of the period was close to zero, i. e., fresh water.

Table 1.--Linear growth of oysters transplanted to Pensacola, Florida, in millimeters.

Source of Oysters	Grand Island Station 17		Lake Mechant Station 20		Pensacola Control		Grand Island Station 17	
Date Transplanted	Feb. 7, 1949		Feb. 10, 1949		Feb. 15, 1949		May 25, 1949	
Number of Oysters	185		110		135		188	
	Average Length	% Increase	Average Length	% Increase	Average Length	% Increase	Average Length	% Increase
Feb. 15	31		61		31			
May 25	47	51	71	16	44	42	33	6 1/
June 30	54	13	78	10	48	9	42	27
Total Increase in Per cent		74		28		55		27

1/ This figure represents per cent increase in length of oysters remaining on natural reef at Station 17 between February 10 and May 25.

These observations indicate that there is nothing inherent in this stock of oysters to prevent normal growth, nor are the oysters infected with microscopic parasites which are markedly deleterious. In the period February to July these oysters were characterized by their excellent growth, development of a better shape, and improvement in the quality of the meat. In the absence of conflicting evidence, it is my opinion that the lack of growth in Mississippi Sound was due to the freshness of the water.

MORTALITY

The preliminary survey of the Mississippi Sound oysters areas affected by the 1945 flood showed, in the summer of 1948, that while there had been good annual sets of oysters there had been no survival of commercial importance. The hurricane of September, 1947 caused considerable mortality on some of the bars. In other areas having high mortalities this storm could not have been the direct cause. Local oystermen felt that the soft mud deposited by the floods, when stirred up by storms, was perhaps instrumental in causing the annual deaths of the small oysters by suffocating them.

Survey of these bars in the first week of December, 1948 showed that a fair proportion of the 1947 spat had survived and that the mortality of the 1948 spat was less than 10 per cent. At this time salinities on the bars averaged 5 to 6.5 ppm. During December, however, precipitation in the region was quite general and resulted in a decline in the salinity.

Experiments were designed to test the relative importance of decreased salinity and turbidity in causing the oyster mortalities. Metal wire trays which could contain up to 400 oysters were obtained through the cooperation of the Department of Wild Life and Fisheries of the State of Louisiana. These cages permitted the placing of the oysters so that part would lie on the bottom in the mud and the remainder could be suspended six inches above the bottom. The weight of the trays prevented their being moved by wave action. Conversely, in some locations where the bottom was soft, the weight of the cage caused it to sink into the mud so as to nearly cover the oysters in the bottom layer.

During the first two weeks in February a comprehensive survey was made of the natural reefs and bottoms in western Mississippi Sound and Lake Mechant. At this time the salinities in Mississippi Sound were less than 1 ppm or entirely fresh. The water was muddy and had other characteristics of river water. All of the oyster grounds examined showed high mortality rates, ranging from 1 1/2

to 8 times what would be expected on a good oyster growing bottom. Mortality rates from 5 to 10 per cent are usual on natural oyster reefs. It should be noted that these conditions prevailed in the absence of any water whatsoever flowing into the area from the Bonnet Carre Spillway or from breaks in the Mississippi River levee system.

Four of the metal wire trays containing from 100 to 400 oysters were placed at Stations Nos. 13, 17, 18 and 19 (Fig. 2). These stations are on a line running roughly north and south, and extending across the ten mile western edge of Mississippi Sound. This line is adjacent to the western limits of successful oyster operations in the past. The majority of the oyster population was lost in this area in the flood of 1945. The oysters placed in the trays were dredged from the natural reef at Grand Island, Station 17. They were less than market size, ranging from 1 up to 3 inches in length, and in very poor condition. It was felt, however, that being native to the region, these oysters would provide a better index as to what was happening on the reef during the period of observation than if oysters in good condition from another area had been utilized. It should be noted too, that they were the survivors of an abnormally high mortality then in progress and might perhaps have been more resistant to the adverse hydrographic conditions.

A second series of four trays was placed in Lake Mechant at this time. These trays extended on a north-south line along the eastern edge of the lake at Stations 20,21,22, and 23 (Fig. 3). The middle locations are where the greatest mortalities occurred in 1945 in this lake. Station 23 was only partially affected by the fresh water. Station 20 is located at that point where most of the fresh water enters the lake and the bottom is too soft for oyster culture. The trays contained from 100 to 200 oysters which were dredged by a commercial boat from leased beds on the west side of the lake. The oysters from the reefs in Lake Mechant, while larger than those used in the trays in Mississippi Sound were stunted in appearance and ranged from 1 to 3 1/2 inches in length. They were in only fair condition and showed a recent mortality of slightly less than 4 per cent. This is within the range found on good oyster producing reefs.

The salinities in the lake at this time were low, from 3 to 5.6 ppm, but the fact that the oysters were feeding and had slight amounts of new shell growth indicated that the hydrographic conditions were, on the average, suitable for maintaining the oyster population.

In Table 2 is a summary of the mortality that was found on the natural oyster bars when the trays were placed in position together with the mortalities that occurred during the four months of observation either in the trays or on the reef. One of the trays was lost and replaced; two other were lost during the final month. On some of the survey trips it was too rough to get the cages out of the water. When it was not possible to obtain the mortality rate from the samples of oysters in the trays, oysters were dredged from the natural reef. Only clean shells remaining hinged together were included in computing the mortality rates on the reef oysters. The final figures in the table show the total estimated mortality which occurred at each station during the period from December, 1948 to June, 1949. The samples in the cages were not large and in some locations it was not possible to find enough oysters to consider the sampling adequate. With these reservations in mind, the mortality figures provide a fair index of the conditions at the stations during the first half of 1949.

Stations 12 and 13, having the highest indices of mortality, are also the two locations lying in closest proximity to the sources of fresh water for this end of Mississippi Sound. The mouth of the Pearl River is only four miles west of Station No. 13. Stations 17, 18 and 19 are located from 5 to 12 miles east of the Pearl River. The mortality rates at these locations were approximately equal and resulted in the loss of half of the meager oyster population still present.

The size of the oysters dying was not restricted to any particular group. When the survivors were measured the distribution of size groups followed a normal distribution curve indicating that larger oysters succumbed as readily as the smaller ones.

Oysters from Station 17 which had been transplanted to Florida and observed during the period February to June, showed a total mortality for the five months of 17 per cent. This rate while only one-third that of Station 17 is still abnormally high. The death of most of these was found, however, to be due to the depredations of mud crabs. Examination showed that the mortality of these oysters at Florida, aside from external predators, was approximately 5 per cent, which is within the accepted range.

At Lake Mechant the condition of the caged oysters was strikingly different. The average death rate was less than 2 per 100 oysters and at least one of the deaths was known to be accidental. This mortality rate is less than what might be expected on a normal oyster bar for a four months period. At Station 20 and 22 the bottom was so soft that the trays of oysters sank into the mud and sand to a depth of six inches.

Table 2.--Percentage mortality on oyster reefs, January through June, 1949

Stations In Mississippi Sound Area II	Observed Recent Mortality on Reef Feb.	Accumulated Mortality Feb.-May 25	Estimated Total Mortality Jan. 1-June 1.
12	55	5	60
13	85	68	95
17	35	23	50
18	16	45	46
19	33	25	50
Stations in Lake Mechant Area III			
20	(1/)	2	2
21	(1/)	0.5	1
22	(1/)	1.3	2
23	4	1	5

1/ These locations were on leased beds which were being harvested at the time of the initial survey so that reliable samples could not be obtained for mortality estimates; or there were no oysters present.

The oysters in the lower compartments were 90 per cent buried, as shown by the discoloration of the shells. Yet in the lower compartments no dead oysters were found.

During this 4 month period, oysters from Lake Mechant which were transplanted to Pensacola, Florida, experienced a mortality rate of 15 per cent. This is similar in degree to the mortality of Mississippi Sound oysters at Pensacola and again, most of this mortality is attributed to the activities of mud crabs.

These ovservations indicate that, from the point of view of mortality rates, the hydrographic conditions at Lake Mechant were favorable for oysters during the first hald of the year 1949, while in this same period, the conditions in the western end of Mississippi Sound were extremely poor for oysters.

OYSTER QUALITY

A standard procedure for determining the quality of food has been to assay its water content. This has been applied to oysters with certa n modification. In this method the ratio of the solids in the oyster meat to the total space occupied within the shells by the living oyster is determined. This statistic is called the Condition Factor. As a criterion for oyster quality, the technique is open to much criticism but has been employed in this survey because of its wide usage. Condition Factors may range from 1 to 17 but in general it may be said that a factor of less than 4 denotes a very poor oyster, from 4 to 7 a fair oyster, and above 7 a high quality oyster. Prime oyster meats will usually have a factor near 10 or above.

A more reliable indication of the quality of oyster meats is expressed simply by the percentage of solids. In Table 3 both figures are given for the series of samples tested at Lake Mechant and Mississippi Sound, as well as for the oysters transplanted from these areas and allowed to grow at Pensacola.

It should be noted from these data that in Mississippi Sound the quality of oyster meats as indicated by per cent solids declined from December to February and then started to improve by May. In Lake Mechant there was a steady increase in per cent solids. Oysters from both of these locations were transplanted to Pensacola in February and by May had improved much more than oysters left in their natural reef. This greater improvement may have been due, in part, to the stimulus of transplantation but was probably due directly or indirectly to the higher average salinity found at the Pensacola location.

Table 3.--Quality of oyster meats.

	Mississippi Sound Oysters		Lake Mechant Oysters	
Date	Condition Factor 1/	Per cent Solids	Condition Factor	Per cent Solids
December	4.5	11	6	12.7
February	4.4	10.1	7.6	13.1
May	3.9	10.3	7.1	13.5
Oysters from each station transferred to Pensacola in February and tested in May.				
May	5.7	15.4	6.1	14.8

1/ 100X the ratio of oyster meat solids in gms to the volume of the shell cavity in ccs.

Table 4. --Number of Nematopsis cysts in Oysters. 1/

Station	7	8	12	17	18	19	21	23	Pensacola
Cysts	116	47	3	78	2	175	53	37	200

1/ Average number of cysts per 10 square millimeters of mantle tissue in each of ten oysters per station.

Parasites and Fouling Organisms

Routine examintations of oysters from the various reefs were made for the relative number of associated fouling organisms on the shells and for the presence of internal parasites, especially the gregarine parasite Nematopsis. This protozoan spends part of its life cycle encysted in the tissue of oysters and some observers believe it causes general debility and possible extensive mortality in the oyster population in some areas. Nearly all oysters examined were infested; the younger the oyster the fewer number of cysts were found, as is to be expected. Compared with oysters growing near Pensacola, Florida, all of the oysters examined had moderate to very light infestations. Table 4 summarizes the recorded observations; numbers of cysts represent the average found per square millimeter in the 100 square millimeters of oyster mantle tissue examined for each station.

The oysters examined at Stations 12 and 18 were spat less than a year old. Presumably they had not had time to become more heavily infested. Older oysters located on adjacent reefs to either side of these stations contained many more cysts.

The variation in numbers of cysts is believed to have little significance geographically or with respect to the hydrographic conditions where the oysters grew. I believe the occurrence of this parasite has no importance in a consideration of the described oyster mortalities.

Many of the oysters examined had microscopic protozoan parasites in their intestinal tracts. No damage could be connected with their presence, and it is concluded that they were of no significance. Had it not been for the absence of food material in the intestinal tract of the oyster, these organisms would probably have not been detected.

Oysters at all stations were examined routinely for the relative numbers of associated animals. These vary from area to area but include mussels, barnacles, boring clams, boring sponge, moss animals, mud worms, and others. In none of the areas examined were they considered sufficiently numerous to be harmful. In general, their numbers were fairly low as a result, in all probability, of the lowered salinity levels.

Turbidity

One factor in the environment on an oyster reef which is demonstrably injurious is the presence, in excess, of particles of silt and other debris. Much blame was attached in the original

descriptions of the mortality in 1945 to the burying and consequent suffocation of the oysters by the enormous load of silt and sand brought onto the reefs by the flood waters. There is little doubt that many acres of natural oyster reefs and planted beds were harmed in this way, although three months after the flood competent investigators found serious mortality without evidence of siltation on some of the reefs. At the present time, four years later, areas such as Point Clear, Waveland, and beds near Petit Pass which supported extensive oyster reefs in the past, are now composed mainly of a sticky-to-soft mud. Soundings made through this mud showed the presence of buried oyster shells. It is difficult to tell how much of this condition is a hold-over from 1945, and how much is a result of the hurricane of 1947. This condition is confined, however, to the western-most part of Mississippi Sound at the present time, affecting perhaps less than 10 per cent of the oyster producing area in the Sound.

Initial investigation of the area in the summer of 1948 suggested that movement of this layer of silt by storm action might account for the reported annual losses of spat since 1945. For this reason, turbidity indices were recorded on all water samples collected in Mississippi Sound and Lake Mechant.

During one particular survey trip in April, 1949 in Mississippi Sound a strong east wind approaching storm proportions made the water very rough and presumably put into suspension a large amount of loose silt. The greatest turbidity recorded at this time differed little from Station 20 in Lake Mechant where oysters flourished under a continuously high turbidity. In my opinion the high turbidity present cannot be a significant factor in itself in the observed oyster mortalities. The surveys indicate also that at the present time, the soft mud on the bottom is sufficiently consolidated so that the average rough water condition will not increase the turbidity enough to be harmful to oysters. The shallowness of the water throughout the Sound insures a thorough mixing of the water with the result that surface and bottom turbidities did not usually vary significantly from each other.

In Area I, turbidities were not apparent to the naked eye and by testing ranged from 10 to less than 1 per cent of light interference.

In Area II, the range and degree of turbidity was far greater but was not enough in itself to prevent the feeding activity of oysters. The range in turbidity during the period February to June was 76.7 to 21.1 being greatest during time of storm and showing no clear cut relationship to the direction of flow of fresh water across the sound from the Pearl River.

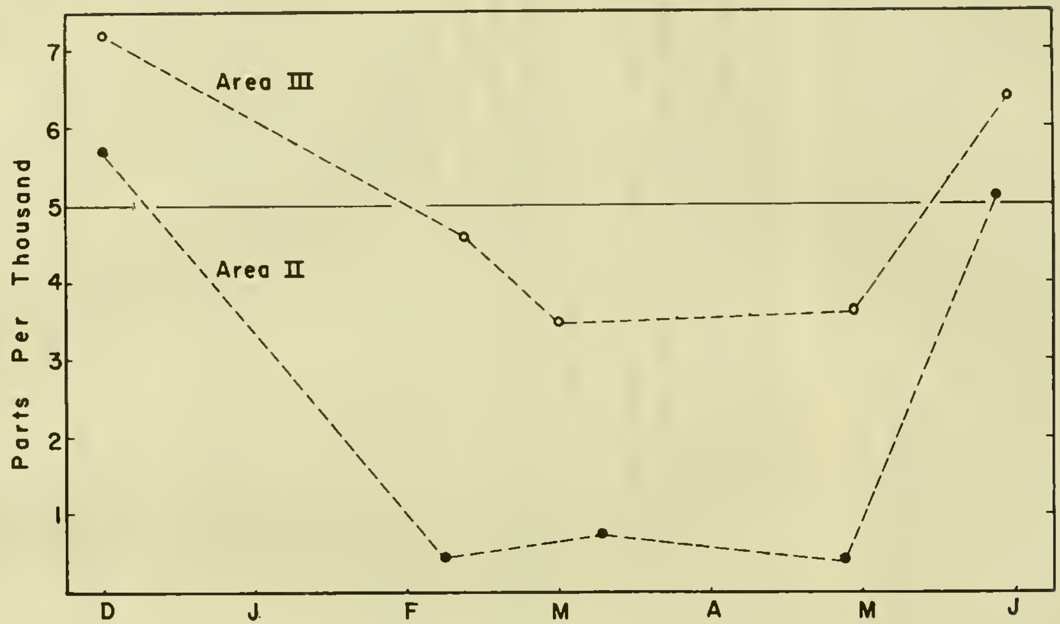

Figure 4. Average salinity levels in parts per thousand in Mississippi Sound, Area II, average of eight stations, and Lake Mechant, Area III, average of four stations, December 1948 through May 1949. A salinity of 5 represents the minimal salt content consistent with growth and reproduction in the oyster.

In Area III turbidities ranged from 70.1 to 25, which parallels the range in Area II. The significant point is that whereas oysters were usually not feeding in Area II they usually were feeding in Area III.

The relative turbidity which existed at the different stations in these surveys had no direct effect on the feeding activity of the oysters or in causing the observed mortalities.

Hydrogen Ion Concentration

Further evidence for the disturbed condition of the water in Mississippi Sound from January to June, 1949 is gained from the tests made for pH of the water samples. The term pH is a convenient method for stating the relative acidity or alkalinity of a solution. In the case of pure distilled water, the pH is 7.0 or neutral. Higher figures indicates a basic solution and lower ones indicate an acidic solution. Sea water is normally alkaline, having a range in pH from 7.5 to 8.4.

In restricted bodies of water such as Lake Mechant and Mississippi Sound, pH values would be expected to differ from the normal range of sea water. Unfortunately, pH values for these areas in other years are not known, but the values found on these surveys indicate a range much greater than might be expected in Mississippi Sound.

In Lake Mechant in April, the salinity varied at four stations from 0.5 to 7.2 ppm. The pH was constant at 6.9. This very slightly acid condition may be explained on the basis of the hydrogen sulphide decomposition taking place in the surrounding marshlands which drain into the lake. I believe this acid condition is normal for the area.

In Mississippi Sound during the first week of March, salinities at five stations varied from 0.2 to 0.8 ppm. The pH values ranged from 8.6 to 9.0 indicating a quite alkaline condition of the water. At these same stations in the latter part of April, the bottom salinity varied from 0.2 to 0.9 ppm, the same as in March, while the hydrogen ion concentration had decreased to such an extent that the water at most stations was 6.9 and only at one station was it as high as 7.1.

These values indicate that the pH was independent of salinity levels in the Sound. The wide variance in pH must be attributed to variations in the sources of fresh water flowing into the Sound from the several rivers. The ranges in pH are not such as would be expected to cause harmful effects on the oyster population.

Temperature

Reference has been made to the effects of water temperature on the oyster's ability to exist in an unfavorable environment. At temperatures below 5°C. (40°F.), the oyster becomes physiologically inactive. Its food and oxygen requirements are almost zero as long as the temperature remains that low. As a result, an oyster may exist in fresh water at low temperatures for a long time. As soon as water temperatures rise above approximately 5°C., the metabolic activity of the oyster increases and it is necessary for it to obtain food and oxygen. If there is not enough food available in the water, or if the oyster will not circulate water because of an unfavorable condition, the oyster utilizes stored food in its tissues, and when this is exhausted, the oyster dies.

During the period December to May, water temperatures in Mississippi Sound were continuously above 5°C. in 1949 and most of the time exceeded 10°C. (50°F.). These temperatures were abnormally high. By the middle of March, temperatures of 20°C. (78°F.) were common. At this temperature level, the oysters become very active in the formation of eggs and sperm, and presumably require additional food supplies. In this period, the low salinity of the water either prevented the oysters from feeding or removed the natural supply of food. The ill effects of fresh water on the oyster were intensified by the mild winter temperatures which the area experienced in 1948-1949.

Salinity

The ability of the oyster to adapt itself to fluctuations in the salinity of its environment is well developed. Since these mollusks flourish naturally in estuaries they must be capable of withstanding not only the increased salinities which occur during times of drought but also the periodic freshening of the water caused by annual freshets and by flash floods from localized increased precipitation. The oyster's resistance to changing conditions is partially a result of the fact that it can close its shells and seal itself off from an unfavorable environment. This, however, is a temporary escape and sooner or later, depending on the temperature, it must reopen its shells. Observations on oysters in many localities and over a period of many years have shown that when salinities decline below 5 parts per thousand (ppm)

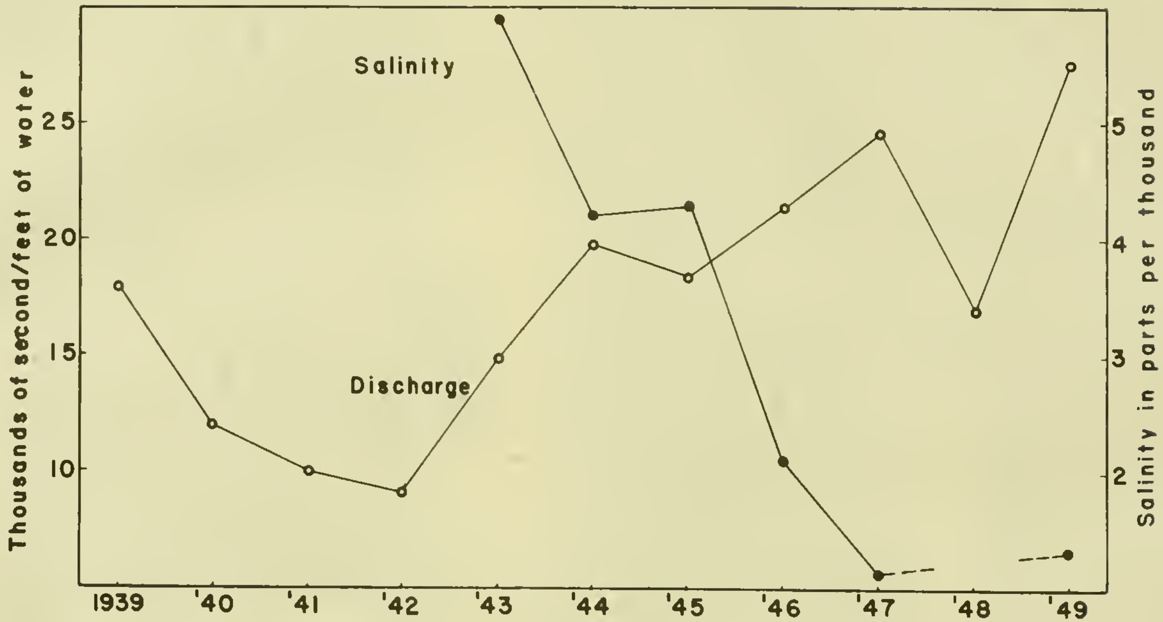

Figure 5. Average daily discharge from Pearl River Basin, January through June, 1939 - 1949. Average bottom salinity in west end of Mississippi Sound, January through June, 1943 - 1949, data for 1948 not available.

for very long, oysters do not thrive. For short periods of time, ten days perhaps in warm water, they may exist in entirely fresh water without untoward aftereffects. The actual length of time that the oyster can survive will depend on the temperature and the amount of stored food in its tissues. If the temperature of the water is low, as in winter, it may survive many weeks. Experimentally, they will survive several months when kept in a refrigerator. However, if temperatures are high, exposure to fresh water for only a few days may be detrimental.

For these reasons, a study of the salinity levels in Mississippi Sound and Lake Mechant over a long period of time helps to evaluate these areas in terms of possible oyster production.

During the past six months, salinity determinations were made at the various stations in Mississippi Sound and Lake Mechant to observe the effects of the annual spring floods in these areas. The data have particular interest in view of the widespread mortality which occurred this past spring. Mississippi Sound is in the shape of a long narrow and shallow basin; because of these physical features, the effect of wind is great on water movement and as a consequence on the salinity. Continued winds from the north and northwest have the tendency to keep out the more saline waters of the Gulf of Mexico. South and southeast winds tend to increase the movement of Gulf water into the Sound. In the same manner, the ebb tide allows the fresh river water to enter the Sound and the flood tide brings into the Sound water having a higher salt content.

The difficulties involved in maintaining continuous records of salinity are too great, so advantage was taken of the water movement to insure the collection of water samples when salinity levels would be at or near the maxima. All of the following data were obtained when the wind movement was either negligible or from the south and southeast. The stage of the tide varied from one quarter to full flood. This means that on the dates indicated, the greatest salinity for the day has been recorded. By spot sampling, it was found that in between the several surveys the salinity levels were both higher and lower.

The average salinities compiled from the data for the period are consistent with the poor condition and high mortality of the oysters in this area. Table 5 shows the range in bottom salinities at a series of stations extending roughly north-south across the west end of Mississippi Sound in Area II. These samples were collected over a 4-hour period while the tide varied between half flood and high water.

Table 5.--Salinity records in Area II, Mississippi Sound, March 9, 1949.

Station	11	12	13	14	15	16	17	18	19	Average
Salinity in ppm.	1.1	0.4	0.2	0.7	0.6	0.8	0.6	0.6	1.1	0.8

Table 6.--Salinity records in Area III, Lake Mechant February 28, 1949

Station	20	21	22	23	Average
Salinity in ppm.	1.2	3.9	4.4	4.4	3.5

The uniformity in water density at any given time is due to the thorough mixing of water in the shallow basin of Mississippi Sound. Thus it is possible to utilize the average salinity of all stations in studying the changes in the area over a period of time. Data are presented in Fig. 4 to show the trend in salinity levels during the period December, 1948 to June, 1949. These figures represent the average of the bottom salinities of all stations in each area. The water was fresh most of the time between February and May, although essentially no water was entering the area from the Bonnet Carre Spillway according to the Corp of Engineers, U. S. Army.

The same treatment of the data for Area III in Lake Mechant does not provide as accurate a picture of salinity conditions in the lakes. Here, the major influx of fresh water is at the northern end of Station 20. From this point, a gradual mixing with salt water takes place along the north-south axis and maximum water densities are found at the southernmost point, Station 23.

The data in Table 6 were collected when the tide was theoretically at 1/4 flood. Actually, at this time there was essentially no tidal flow.

In Area I, salinities generally averaged above 5 ppm and were at some times and at some stations as high as 18.6 ppm. The variations, however, were so great that the average values do not present an accurate picture of the trend during the period of the surveys.

Summary of Field and Experimental Data

The pertinent conclusions which may be derived from the data collected in this study may be briefly stated at this point to advantage.

Area I. The growth, mortality and condition of the oysters in this section of Mississippi Sound indicate that in early spring the salinity levels were minimal for the support of the populations. These conditions started to improve late in April and by the middle of May a normal environment for growth and reproduction was attained.

Area II. The growth, mortality and quality of oysters in the west end of Mississippi Sound indicate that this environment was extremely unfavorable. There was no evidence that internal or external parasites were present in sufficiently large numbers to affect the oysters seriously. The physical factors in the environment such as temperature, turbidity and pH were within the range found in other localities where oysters thrive. Transplantation of these oysters to other areas demonstrated that

Table 7.--Pearl River Basin discharge rates and Mississippi Sound salinity levels

Year	Discharge Rate in second/feet 1/	Salinity in parts per thousand 2/
1939	17995	
1940	12026	
1941	10043	
1942	9410	
1943	14909	5.9
1944	19845	4.2
1945	18390	4.3
1946	21751	2.15
1947	24696	1.13 3/
1948	17067	No data
1949	27602 4/	1.3 5/

1/ Average daily discharge for the period January through June inclusive.
2/ Average bottom salinity for the period January through June inclusive.
3/ January through March.
4/ Unpublished, provisional data.
5/ February through May.

there were no inherent factors to prevent normal growth and development. Finally, the evidence points to the conclusion that a low salinity level was the single important factor in causing the poor conditions which existed in the oyster population.

Area III. The growth, mortality and quality of oysters from Lake Mechant and connecting bayous indicate that this environment was suitable for normal growth and reproduction but that the salinity levels for several months were probably close to the lower limits necessary for the commercial production of oysters.

SIGNIFICANCE OF PEARL RIVER DRAINAGE BASIN

The question then naturally arises,--why should this area in Mississippi Sound suddenly, i. e., since the flood of 1945, become either unproductive or have extensive mortalities? According to local oystermen the area under consideration has been in the past the source of some excellent oysters, but we have little evidence as to the rate of production or whether production was maintained every year. The Bonnet Carre Spillway has not operated during the four years, if we except a few days leakage in the latter part of February, 1949. The amount of water entering Lake Pontchartrain at that time was the equivalent of only an over-night rainstorm according to the New Orleans District Engineers. The estimated maximum flowage rate of 1007 second/feet persisted for a very short time. If fresh water from only the Pearl River is the cause, we must assume that either mass mortalities have occasionally occurred in the past or that some recent changes in this drainage basin have taken place.

For these reasons, an investigation was made of the quantities of water discharged by the Pearl River and its tributaries into Mississippi Sound. The distance from the mouth of the Pearl River to the oyster reefs most carefully studied varies from 4 to 10 miles north and west. The Pearl River drainage basin extends some 200 miles due north of the west end of Mississippi Sound and covers more than 8,000 square miles of land within the States of Mississippi and Louisiana.

Fortunately for our purposes, discharge records have been maintained during the past ten years at Pearl River Basin stations approximately 50 miles up from Mississippi Sound. This means that the discharge rates listed are lower than the amount of fresh water which actually flowed into Mississippi Sound.

During the period January, 1943 to March, 1947, the Louisiana Department of Wild Life and Fisheries made daily salinity tests at several stations in the west end of Mississippi Sound. Their records show that average monthly salinities too low for oysters occurred with only one exception in the first half of each year. Therefore, in showing the rates of Pearl River Basin discharge into Mississippi Sound, the average rates for the period January to June only are considered. In Table 7 and Fig. 5 these data are compared with the records obtainable for average salinities during a part of this same period of time. Daily and monthly figures have been averaged so that these charts present the trend during the years rather than precise figures for any individual date.

These data demonstrate that in the years 1946, 1947 and 1949 when mass mortalities occurred in the west end of Mississippi Sound, there were greatly increased rates of fresh water discharge from the Pearl River Basin. The preliminary survey of the Mississippi Sound area in the summer of 1948 and the second survey made in December of that year showed oyster mortalities of le s than 10 percent. On the basis of this, I had predicted that in the winter of 1948-49 there would be a return to normal growth on these reefs. However, the extraordinarily high discharge from the Pearl River in early 1949 prevented such a return to normalcy.

The importance of this watershed in controlling the hydrographic factors in Mississippi Sound is indicated by the fact that during the 6 years for which we have data the salinity is directly correlated with the flow from Pearl River. This relationship holds true even for the year 1945, when the additional mass of water entered the area from the Bonnet Carre Spillway. This presumably is due to the averaging of figures for the six months period and obviously would not hold true for the 56-day period when the spillway was flowing.

On the basis of the records for the past ten years, it is reasonable to expect that whenever the mean daily discharge rate from the Pearl River Basin exceeds 20,000 second/feet for the period January through June, there will be significant oyster mortalities in the west end of Mississippi Sound. This conclusion is based also on the provision that the high discharge rate is spread over an extended period rather than being confined to a flood of short duration in the colder months. The validity of this hypothesis is further shown by the records of 1948. In this year, the average daily discharge rate in the period January through June was only 17,000 second/feet. From this it would have been possible to predict a low oyster mortality in the summer and fall of 1948. Conversely, when surveys showed a low oyster mortality on the reefs in the west end of Mississippi Sound in the latter half of 1948, it was possible to assume a low average discharge rate from the Pearl River even before the records had been examined.

The inference may be made also from these data that in 1945 the Pearl River Basin did not contribute sufficient fresh water to have caused excessive mortalities by itself. The only references found in the literature to oyster mortalities in the past caused by the Pearl River were based on inadequate sampling. However, Weatherby in 1927, and Viosca in 1937 noted mortalities of 10 per cent or less, which they attributed to fresh water from this source.

Rates of water discharge are made at the Pearl River Basin stations by recording the height of a wire weight gauge. The highest stages noted in the past occurred in 1874 and 1900 when gauge heights were estimated to be 20.2 and 19.7 feet respectively. It is noteworthy that in the first six months of 1949, the recorded guage height exceeded 19 feet on 61 days and exceeded 20 feet on 2 days. Geological Survey engineers attributed this increased discharge rate entirely to increased rainfall in the drainage basin.

REHABILITATION OF OYSTER REEFS

In discussing the rehabilitation of the oyster areas examined, there are several points which must be taken into consideration. In the natural course of events an oyster bar rehabilitates itself provided there is an adequate amount of cultch present, that there is a good setting and growing rate, that too intensive harvesting is not practised, and that further natural disasters do not occur. Depending on the interaction of these factors, rehabilitation will require from 2 to 5 years, possibly longer. Much of Mississippi Sound usually provides a good natural environment for oysters and now, as is to be expected after four years, a major part of the natural rehabilitation possible has already taken place on those bars damaged in 1945. The passage of time has made extensive cleaning operations, removing the debris and dead shells from the bottoms no longer necessary. The unusually high natural setting rate of young oysters in the past few years in most of these areas shows that cultch in the form of clean oyster shells is the only thing necessary to bring about a complete restoration of the reefs. Along the Gulf Coast the cost of planting shells varies from 40 to 50 cents a barrel, so that adequate shell plantings may be carried out at a unit cost of approximately $125.00 per acre. However, the planting of small seed oysters, which are available to some extent, may be done for slightly increased costs. The planting of seed would shorten the period of restoration by 1 to 3 years, depending on the size of the oysters planted.

Rehabilitation of the oyster reefs, then, is or can be an accomplished fact. An item of equal importance is whether or not it is desirable to bring about further rehabilitation and replant the beds. That is to say, is there justification for spending federal,

state or private funds for re-establishing reefs in areas where there exists the possibility of their being destroyed in 1 or 5 years by further disturbances in the environment? In the Congressional hearings concerning the mortalities of 1945, there were many opinions expressed as to whether or not the action of these flood waters was a natural catastrophe or one caused by the construction of the spillway and various levees and dams. The fact exists that flood waters naturally occur periodically every five years or so, and whether they spill over through man-made channels, are diverted by man-made dams and levees, or flow through natural breaks in the system of waterways, they are going to cause damage. If flood waters are high enough, they cannot escape in the delta area without flowing over oyster reefs. The magnitude of the flood waters and the time of the year in which they occur are governed purely by natural laws, and it is these two factors which will determine the extent of damage to the oyster reefs.

Oyster mortalities have been recorded in the past and they will occur in these areas in the future. It is of interest and relevant to quote at this point from a publication by L. R. Cary. Writing in some detail concerning the biological aspects of the oyster industry of Louisiana in 1907, he said:

> "In the greater part of the oyster producing area of this state, the most damaging destructive agent is the fresh water which from time to time breaks away from natural restraints and for a greater or less period of time makes the water over the beds so fresh that the oysters are either killed outright, or made so poor that they are useless for market for some time. The destruction from the spring freshet is of pretty regular occurrence, more or less damage being done in some part of the state each year, and large areas of oyster producing bottom are periodically denuded of their growth."

This statement is just as true today as it was at the turn of the century.

The oysterman must place his beds in those locations least likely to be damaged by the average flood waters. To spend money on reefs situated near likely exits for flood waters, no matter how good an environment it is for oysters in "normal" years, is biologically and economically unsound.

A review of the history of floods in these areas during the past 50 years, in conjunction with the present status of the reefs, suggests the following recommendations:

1. The west end of Mississippi Sound is periodically subject to floods which have emerged through natural and man-made crevasses. Area I, which contains the major oyster producing bars of Mississippi,

is sufficiently far removed from the source of fresh water so that in ordinary flood years, mortalities will be negligible although growth of the oysters may be inhibited for several months. The replanting of the reefs in this area with seed oysters or clean cultch is biologically reasonable and would be economically advantageous.

2. The oyster reefs in Area II are more susceptible to possible flooding from the Mississippi River and are adjacent to the Pearl River which in the past four years has had spring floods of unusual magnitude. This section of Mississippi Sound may be classified as marginal with respect to growing oysters. It may produce fine crops of oysters for many successive years but it may just as likely fail in production for as many more. Oyster farming in this area will always have more than the usual element of chance. Environments such as this have counterparts in all oyster growing areas which are adjacent to sources of fresh water. An accepted method of culture is to take advantage of what nature provides in good years. When the oysters are large enough to move, transplant them to safer growing areas or bedding grounds. In using the reefs in this manner as a seed bed, it is necessary to supply shells to which the young oysters attach themselves. In years when there is no set, there will usually be little fouling of the shells so that they can be used the next year and there will be little, if any, financial loss involved. Bottoms in this area which are still not usable because of sand or soft mud should not be improved. The cost would be greater than the probable value of oysters that might be produced. Money and effort can be spent to much greater advantage in improving the many acres of non-productive oyster bottoms in Mississippi Sound and in the Delta area which are far enough removed from sources of fresh water.

3. In Lake Mechant and its connecting bayous, Area III, the replanting of the bottoms has already been accomplished through private enterprise. The wisdom of this could not be foreseen, but the history of flooding in this area indicates a better than even chance for moderately successful oyster harvesting. It should be borne in mind, however, that the construction of the levee system on the Atchafalaya Floodway (Fig. 1) and the confining of the waters at the southern outlets in the neighborhood of Morgan City, places a continuing threat to the property lying south and eastward, including Lake Mechant. In years of normal spring floods, the waters will be retained in the artificial barriers, but in years of excessive floods, as in 1945, there will inevitably occur an inundation of Area III. The effects of such flooding on the oyster beds will again be entirely dependent on natural causes, including the magnitude of the flood and the time of the year in which it occurs. The desirability of spending money in building reefs in this area is highly questionable. A better use for the grounds would be as an area for "fattening" oysters in the periods between spring freshets.

SUGGESTIONS FOR FUTURE WORK

The dramatic floods in Mississippi Sound in 1945 and the less obvious but equally disastrous floodings of the past four years focus attention on the seasonal threat which excess fresh water imposes on the oyster industry.

Precise data on the harmful effects of fresh water on oysters at different times in the year are entirely lacking. We do not know if the freshness of the water is the single destructive agent or whether it affects oysters only indirectly. Possibly, fresh water causes starvation indirectly by killing the oysters' food supply. Its effect may be a mechanical one in swelling the tissues which in turn prevents water containing food from circulating in the oyster. It has been found in the past that the sudden intrusion of large amounts of fresh water for a short period of time has been very beneficial to the oyster reefs. However, we do not know how much water and under what conditions of time and temperature is of value. These and many related problems must be studied before we can provide detailed advice on the desirability and possibility of rehabilitating and maintaining oyster reefs located in marginal areas wherever they occur.

We may obtain the answers to these questions only by directing our efforts on a long range program of testing and observing. Experiments must be conducted under controlled conditions in the laboratory as well as under natural conditions of flooding on the reefs. The Gulf Coast is especially suitable for a research program of this character because of its several rivers of varying magnitude which flow into oyster producing areas. The relatively warm climate enables the oyster to remain active throughout the winter and it is possible to conduct experimental work in the field at a time when Atlantic Coast oysters are hibernating.

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APPENDIX A

Description of Sampling Stations, June 1, 1949

Some of the sampling stations were located on natural, uncultivated oyster reefs. Other stations were on reefs which have been cultivated to some extent for the past 50 years. The oysters were collected with the use of commercial oyster dredge boats, hand tongs and in some cases where the water was sufficiently shallow, the oysters were gathered by hand from the bottom.

Area I (Fig.2)

Station 1 - Buoy Reef. This bar has an average depth of 9 feet with a good oyster bottom of broken shell and stiff mud. Oysters were uniformly small and there was no evidence of mortality. The oyster meats were in only fair condition but all oysters were feeding. New shell growth was just starting; the gonads were half spawned. Oysters and shells were covered with a new set of oysters approximately one to two weeks old. One cluster of oyster drill egg cases was found but no adult snails. Fouling organisms on oysters were moderately numerous. The reef is depleted and needs additional shells to catch the young oysters. The presence of drill eggs indicates that this pest may cause a serious loss of oysters in seasons when the salinity level is higher.

Station 2 - Cat Island Spit. This reef has a hard shell bottom mixed with some sand. There is an average depth of 10 feet. In August 1947 it was heavily planted with shells. The oysters were mostly small and there was approximately an 8 per cent mortality. Five drills were found and seven clusters of drill eggs in approximately 1 1/2 barrels of bottom material but apparently only a few of the dead oysters had been killed by snails. Fouling organisms were moderately numerous. There were many recently set spat on oysters and shells. This bar supports a good growth of oysters but drills probably cause considerable damage. The oysters were feeding and the gonads were about half spawned.

Station 3 - Cat Island Channel. This area is the deepest reef in the area extending down to 25 feet. The bottom of firm mud mixed with shells is mostly depleted. The oyster population is made up of large old shells and a few large old oysters. There was no evidence of recent mortality. The oysters were in fair condition, about 1/4 spawned and actively feeding. A very few new set were found on the old shells.

The old shells were much eroded but live oysters had few attached fouling organisms. The absence of small oysters and spat indicate this is usually a poor setting region.

Station 4 - Fletcher Key. This is a good oyster reef having a firm broken shell bottom at an average depth of 9 feet. Commercial harvesting was carried on here up until April. Approximately 95 per cent of the present population is made up of oysters less than 2 inches long. Mortality amounted to less than 5 per cent. The shells and oysters were covered with spat less than two weeks old. The oysters were in fair to good condition, feeding, and with gonads about half spawned. Fouling organisms were numerous but no oyster drills or drill egg cases were found.

Station 5 - Pelican Key. This reef is made up of a hard broken shell bottom with an average depth of 8 feet. The oyster population at present is badly depleted and made up almost exclusively of small seed oysters. There was no evidence of recent mortality. The oysters were in fair condition, feeding and with gonads approximately 1/4 spawned. This reef showed more new growth, up to 5 mm., than the other bars examined. There was a heavy recent set of small oysters. Fouling organisms were not numerous. No oyster drills or egg cases were observed. This area is good for catching seed oysters but is lacking in cultch.

Station 6 - Telegraph Key, South Side. This reef is composed of broken shells on a firm bottom. All of the oysters were less than market size and showed no evidence of mortality. The oysters were in fair condition, feeding and had gonads which were approximately 1/2 spawned. There was only slight evidence of new shell growth. Fouling organisms were practically absent. There had been a recent heavy setting of oyster spat. This reef has an inadequate amount of cultch to build up the population.

Station 7 - Bayou Pierre. This station was established for collecting only hydrographic data.

Station 8 - Square Handkerchief, West Side. This reef has an average depth of 10 feet; the bottom is hard, made up of old broken shells mixed with some sand. The reef was planted with seed oysters during March and April, 1949. The oysters were growing well and showed no evidence of dredge damage or recent mortality. The meats were in only fair condition, some of them showed green deposits in the mantle. The gonads were about 1/2 spawned. Fouling was moderate, but the shells had been riddled by sponge and boring clams that had later died. There was a very heavy set of young oysters but the amount of cultch on the reef is inadequate.

Area II (Fig.2)

Station 9 - Waveland. This is an extensive tonging reef paralleling the shore and having an average depth of 10 feet. During the hurricane of 1947 it was seriously damaged when a foot deep layer of soft mud covered the bottom. At the present time there are practically no shells or oysters in the area. The bottom is still too soft to be planted without the addition of considerable strengthening material.

Station 10 - East St. Joe. This is a fairly small area having an average depth of 15 feet. The bottom is hard shell and gravel. The small population of oysters present appears to be entirely from the 1948 set. These and the scattered old shells were covered with the 1949 set of oysters which was about two weeks old. The shells were white and clean, which is a typical condition following exposure to fresh water. The population showed a mortality of 26 per cent. The oysters were feeding but there was no new growth. Fouling organisms were not numerous. This bar shows transitional characteristics between Area I and II. Although there was considerable mortality present, there was also a good set of new oysters.

Station 11 - Bayou Caddy. This reef has an average depth of 6 feet and is made up of a hard sand, mud and gravel mixture on the inside edge. The outer edge of the bar has a 6 inch overlay of soft mud. There are almost no shells or oysters present. This is one of the areas that has not recovered from the effects of the hurricane in 1947.

Station 12 - Three Oak Bayou. This area consists of only a few acres of a firm mud-sand mixture. The water averages 5 feet in depth. All of the oysters present, and there were very few, were less than 2 inches long. The mortality on the reef was in excess of 50 per cent and none of the remaining oysters had put on any new growth. The condition of the oyster meats was very poor and the oysters were not feeding. There was no new set; fouling organisms were scarce.

Station 13 - Lower Point Clear. This area is a natural reef having an average depth of 10 feet and a bottom made up of mud and sand. On the initial survey in February, 85 per cent of the small population present was dead. By the end of May, 68 per cent of a new sample of oysters transplanted to the area had been killed. The rare oysters that could be found on the reef in May were in extremely poor condition and showed no growth. Approximately only 6 out of 10 of these were feeding. The remainder apparently were dying. Most of the usual associated fouling organisms, such as barnacles and bryozoa were dead but a few living mussels were found. There was no new set of oysters.

Station 14 - Grassy Island, Station 15 - Midway between Grassy Island and Grand Island, and Station 16 - Grand Island, East Side, were established for collecting hydrographic data only.

Station 17 - Grand Island. This area contains a natural hard shell reef in about 6 feet of water. Inshore toward the island the bottom becomes more sandy. During February, 35 per cent of the population was found dead and by May another 25 per cent had died. Mortality occurred equally among the small and larger oysters. These were mostly less than market size with clean white shells characteristic of oysters that have been exposed to fresh water. A few barnacles constituted the only live fouling organisms. In May, the oysters still had glassy transparent meats, but they were feeding and there were traces of developing gonads in all. Most of the oysters had a few millimeters of new shell growth. There were no new spat at this time.

Station 18 - Petit Pass Island. This area was the location of a private lease and before 1945 had been a good growing region. The bottom was a sticky-to-soft mud; average depth of water was 10 feet. There were numerous old dead shells on the bottom, presumably remnants of the population killed in 1945. These shells were covered with successive layer of dead spat and inch or less in length. The few live oysters were all less than 2 inches long. In February, there was a mortality of 16 per cent and by May an additional 20 par cent had died. Most of the oysters were feeding but the meats were still very poor. There was a slight indication of new growth and development of spawn but there were no 1949 spat.

Station 19 - Three Mile Pass. This area is a natural reef which had received additional shell plantings. The average depth of water is 6 feet and the bottom is hard or sticky, changing to soft mud on the edges. There was a fairly large population of oysters, all of them small. Many of the 1948 oysters were as large or larger than obviously older oysters. The February mortality amounting to 27 per cent had been increased to 50 per cent by the end of May. At this time all of the oysters were feeding and had 1 to 2 millimeters of new growth and a few had well developed gonads. There was no evidence of 1949 spat. All of the oysters showed typical smooth white shells.

Area III (Fig. 3)

Station 20 - Raccourci. This area lies at the north end of Lake Mechant where in normal periods the major portion of the fresh water drainage enters the lake. The bottom is a soft sand and mud mixture lying at a depth of 3 to 6 feet. There are no oysters growing here naturally.

Station 21 - Deer Bayou. This area is located on a private lease which has been used as a bedding ground, that is an area where oysters are placed to grow and "fatten" prior to harvesting. The water averages 6 feet in depth and the bottom consists of a sticky sand and mud mixture.

Station 22 - Mud Lake. This area is in all respects similar to the station at Deer Bayou. The oysters located here in 1945 are reported to have suffered almost a complete mortality. In February 1949, the planted oysters here were in good condition.

Station 23 - Grassy Island. This area supports a natural growth of oysters in water varying in depth from 2 to 5 feet. The bottom is a firm sand and mud mixture. The oysters were clustered, with heavy eroded shells and gave the appearance of being 3 to 4 years old although they were mostly less than market size. This area was relatively unaffected by the flood waters in 1945. The oyster meats were only fair in appearance, but the gonads were well developed and there were many young oysters from the 1949 generation.

Table 8.--Summary of conditions on oyster reefs as of June 1, 1949

Station Number	Bottom Condition	Market Oysters Per cent	Small Oysters Per cent	1949 Spat	Oyster Quality	Recent Mortality Per cent	Growth mm.	Fouling Animals
Area I								
1	Good	5	95	Many	Fair	0	2	Many
2	Do.	25	75	Do.	Do.	8	2	Moderate
3	Do.	95	5	Rare	Do.	0	0	Few
4	Do.	5	95	Many	Do.	5	5	Many
5	Do.	1	99	Do.	Do.	0	5	Few
6	Do.	0	100	Do.	Do.	0	2	Scarce
8	Do.	40	60	Do.	Do.	0	5	Few
Area II								
10	Good	0	100	Many	Fair	26	0	Scarce
12	Fair	0	100	0	Poor	60	0	Do.
13	Do.	0	100	0	Do.	95	0	Do.
17	Good	5	95	0	Do.	50	2	Do.
18	Poor	0	100	0	Do.	45	2	Do.
19	Fair	0	100	0	Do.	50	2	Do.
Area III								
21-23	Good	35	65	Many	Fair	4	5	Moderate